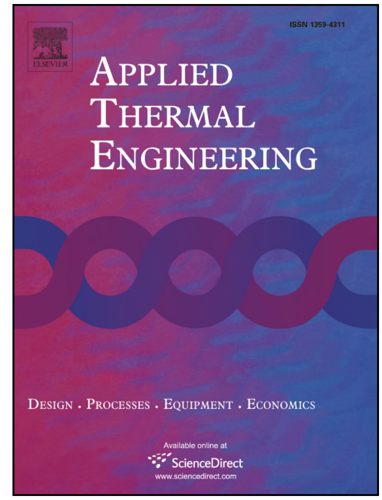
Accepted Manuscript



Multi-Factor Optimization Study on Aerodynamic Performance of Low-Pressure Exhaust Passage in Steam Turbines

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PII: S1359-4311(16)31862-2
DOI: http://dx.doi.org/10.1016/j.applthermaleng.2017.05.136
Reference: ATE 10450

To appear in: *Applied Thermal Engineering*

Received Date: 22 September 2016
Revised Date: 2 May 2017
Accepted Date: 25 May 2017

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ABSTRACT

The influence of multiple factors on low-pressure exhaust passages in a 600-MW steam turbine was investigated by orthogonal experiment. Numerical optimization of the exhaust-passage installed guide devices was performed according to the major factors. The compressible three-dimensional Navier–Stokes equations and standard k-ε turbulence model were solved by the CFX numerical simulator. The results show that the last-stage blades (LSBs), boiler feed-pump turbine, and steam-extraction pipeline as well as their interactions have some influence on the aerodynamic performance of the exhaust passage, in which the LSB is the most significant. This influence should be considered in the optimization. Installing guide devices in the condenser throat can reduce the fluctuation degree of the velocity at the condenser-throat outlet. Under a 100% turbine heat-acceptance condition, the total pressure drop in the exhaust passage increases by only 0.72%, whereas the static-pressure recovery coefficient is improved by 19.49%. In addition, the optimization can be applied to different loads, which can obviously improve the aerodynamic performance of an exhaust passage with small energy loss.

Key words

Steam turbine; exhaust passage; orthogonal experiment; last-stage blades; aerodynamic performance

1 Introduction

In recent years, the 600-MW steam-turbine generating units account for over 36.8% of the total installed capacity of thermal power plants in China [1]. During the operation of a steam turbine, condenser performance is critically important for unit economy [2]. Cuevas et al. [3] pointed out that the flow characteristics of a working medium in a condenser largely influence the efficiency. The influence of non-condensable gas on the vacuum of a condenser was studied by Strušnik et al. [4]. However, the influence of the flow condition in the condenser inlet on the vacuum has been ignored. The exhaust steam of a last-stage blade (LSB) turns 90° from the axial to the radial direction through the exhaust hood. Thus, the aerodynamic field exhibits a three-dimensional complex change. Research shows that the energy loss of the exhaust passage accounts for 2% of the total loss in a steam turbine [5]. An exhaust passage with poor aerodynamic performance [6] and a vacuum-pumping system that deviates from the power plant practice [7] both reduce the unit economy. Therefore, we need to study the aerodynamic performance of the exhaust passage because it plays an important role in the condenser vacuum and thus optimize the unit and save energy.

At present, the numerical simulation method is employed to study the aerodynamic performance of an exhaust passage [8]. The exhaust passage is composed of the exhaust hood and condenser throat. Many factors affect the aerodynamic performance because of its complex structure. The aerodynamic performance of an exhaust passage is unstable due to the uneven flow field at the LSB outlet, and the flow characteristics can be studied by the numerical method by coupling the LSB with the exhaust hood [9-13]. Moreover, the uneven flow field in the condenser throat caused by many factors such as the large-diameter steam-extraction pipeline in the condenser throat and boiler feed-pump turbine directly influences the condenser performance [14]. However, current research on the aerodynamic performance mainly focuses on the single exhaust hood with one condenser

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